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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RELIABILITY OF DEVICES USED IN FIBRE OPTIC SYSTEMS – GENERAL AND GUIDANCE

FOREWORD

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IEC 62721, which is a technical report, has been prepared by IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

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INTRODUCTION

TC86 (Fibre optics) is a group that reviews and implements the standardization of optical fibres and optical cables, optical interconnecting devices, passive and active optical components and modules, and optical sub-systems. As these optical components and modules are used for telecommunications as well as data communications systems, the reliability required for these are extremely high. Since the 1980s, when fibre optic communication systems were first deployed for commercial use, the reliability of optical fibres, optical components and modules has been examined and checked. As a result, reliability theories are nearly completely established for optical fibre, optical connectors, optical passive components and optical active components.

How to check reliability differs depending on the type of optical device. For example, for optical fibres, it is measured by the probability of fibre breaks under the condition of constant stress. Optical passive components are generally tested using accelerated deterioration tests under high temperature and high humidity conditions. For the reliability of laser diodes (LD) (a typical optical active device), the primary failure mode is a decrease of optical output power and an increase of threshold electric current caused by the increase of the leakage of electrical current in the active layers of the LD chip. The lifetime has an inverse correlation with the drive current.

In addition, the industry has established and uses standard reliability evaluation tests developed for the purpose of commercialisation in addition to the approach of estimating the lifetime by failure mode analysis mentioned above.

Information on failure mode and lifetime estimates are discussed and summarised in many documents prepared by the Subcommittees (SC) and Working Groups (WG) of TC86. Test items and conditions for reliability qualification tests are described in documents prepared and set forth by each SC.
1 Scope and objective

This technical report provides information on the IEC documents concerning reliability for optical fibres, optical connectors, optical passive components, optical active components, optical amplifiers, and optical dynamic modules used for optical fibre communications.

Documents on reliability include summaries of reliability theory and quality management methods, technical information on failure mode analysis and failure mechanisms, lifetime and fit-rate estimates using acceleration tests, test items, conditions, and pass/fail criteria in reliability qualification tests, and tests and measurement methods for optical fibres, optical components, and optical modules.

Each SC in TC86 has already created documents on reliability. This technical report provides this information in a user-friendly manner.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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IEC 62005 (all parts), *Reliability of fibre optic interconnecting devices and passive components*

IEC 62007-2, *Semiconductor optoelectronic devices for fibre optic system applications – Part 2: Measuring methods*
IEC 62150 (all parts), *Fibre optic active components and devices – Test and measurement procedures*

IEC 62343-2, *Dynamic modules – Part 2: Reliability qualification*

IEC 62343-5-1, *Dynamic modules – Test methods – Part 5-1: Dynamic gain tilt equalizer – Response time measurement*

IEC 62572-3, *Fibre optic active components and devices – Reliability standards – Part 3: Laser modules used for telecommunication*

IEC/TR 62048, *Optical fibres – Reliability – Power law theory*

IEC/TR 62343-6-6, *Dynamic modules – Part 6-6: Failure mode effect analysis for optical units of dynamic modules*


IEC/TR 62627-03-01, *Fibre optic interconnecting devices and passive components – Part 03-01: Reliability – Design of an acceptance test for fibre pistoning failure of connectors during temperature and humidity cycling: demarcation analysis*
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Generic information on reliability

Reliability generally means the characteristics of keeping the required performance over a long period of time and/or on repeated operation (driving). Components and modules degrade and finally fail after long term operation. Reliability is usually expressed in this case as failure rate per unit time (e.g. hours) or a time. The curve of the failure rate is called a bathtub curve, and is generally divided into three regions: initial failure region, random failure region, and wear-out failure region. Screening tests are sometimes applied to reduce the initial failure rate.

In the random failure region, the failure rate is independent of the operating time. In the wear-out failure region, the failure rate increases as operating time extends. Generally, reliability is expressed by the failure-in-test (fit) rate in the random failure region, and in the wear-out failure region by the accumulated failure rate depending on the operating time of the product.

There are two types of reliability: design reliability and field reliability. Design reliability is generally estimated by accelerated test results and/or calculated by a cumulative total of fit rates of the parts and materials. Field reliability is generally calculated by the total failures and the total operating hour volume in the field.

The following shows the standard approach to design reliability:

– Conducting a failure mode analysis and analysing the performance of the parts which degrade and the factors that accelerate degradation;
– Determining the acceleration test conditions and the pass/fail criteria based on the results of failure analysis;
– Carrying out acceleration tests under different conditions and obtaining the appropriate functions to indicate the lifetime (i.e. the failure function (Weibull distribution, lognormal distribution)) and the acceleration factor;
– Carrying out lifetime tests under suitable conditions of the accelerated tests to obtain more accurate parameters for the lifetime distribution function and calculating the failure rate and the accumulated failure rate.

Besides the reliability estimate obtained in the procedures based on the failure mode analysis described above, conventional reliability qualification tests have been used for many types of optical components and modules that consider the component environment. In particular,